US009188671B2

(12) United States Patent
Mugiuda et al.

(10) **Patent No.: US 9,188,671 B2**

(45) **Date of Patent: Nov. 17, 2015**

(54) **MOVING BODY DETECTOR**

(71) Applicant: **PANASONIC CORPORATION**, Osaka (JP)

(72) Inventors: **Toru Mugiuda**, Mie (JP); **Fumihiro Kasano**, Osaka (JP); **Hidehiko Fujikawa**, Mie (JP); **Yutaka Abe**, Mie (JP); **Toshimasa Takagi**, Mie (JP); **Kazushi Goto**, Mie (JP)

(73) Assignee: **PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD.**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 45 days.

(21) Appl. No.: **14/347,574**

(22) PCT Filed: **Sep. 24, 2012**

(86) PCT No.: **PCT/JP2012/074321**
§ 371 (c)(1),
(2) Date: **Mar. 26, 2014**

(87) PCT Pub. No.: **WO2013/051408**
PCT Pub. Date: **Apr. 11, 2013**

(65) **Prior Publication Data**

US 2014/0241125 A1 Aug. 28, 2014

(30) **Foreign Application Priority Data**

Oct. 4, 2011 (JP) 2011-219786

(51) **Int. Cl.**

G08B 29/16	(2006.01)
G01S 15/52	(2006.01)
G01S 7/52	(2006.01)
G01S 13/56	(2006.01)
G08B 13/16	(2006.01)
G01S 7/40	(2006.01)

(52) **U.S. Cl.**
CPC ***G01S 15/523*** (2013.01); ***G01S 7/52004*** (2013.01); *G01S 7/4004* (2013.01); *G01S 13/56* (2013.01); *G08B 13/1627* (2013.01)

(58) **Field of Classification Search**
CPC G08B 29/16; G08B 17/00; G08B 13/1627; G01S 15/523
USPC 367/90, 94; 340/435, 438, 540, 541, 340/545.5, 552, 554
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,746,220	B2 *	6/2010	Takagi et al.	340/435
8,218,395	B2 *	7/2012	Kasano et al.	367/90
2005/0219117	A1	10/2005	Hiromori et al.	

FOREIGN PATENT DOCUMENTS

EP	0 825 455	A2	2/1998
JP	58-135475	A	8/1983
JP	2005-017290	A	1/2005
JP	2009-281890	A	12/2009

OTHER PUBLICATIONS

International Search Report issued in International Application No. PCT/JP2012/074321 with Date of mailing Oct. 23, 2012, with English Translation.

* cited by examiner

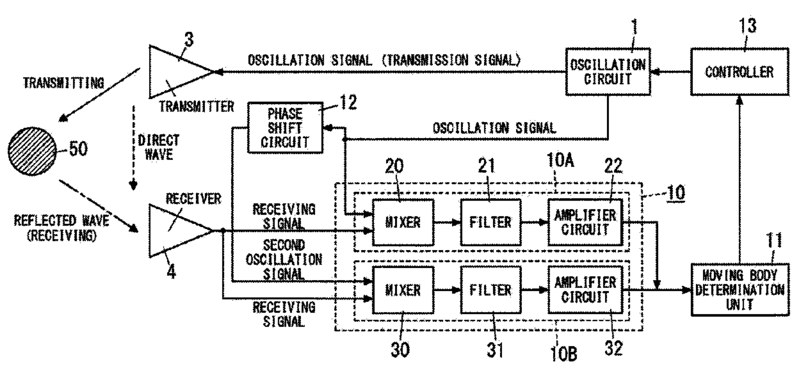
Primary Examiner — Tai T Nguyen

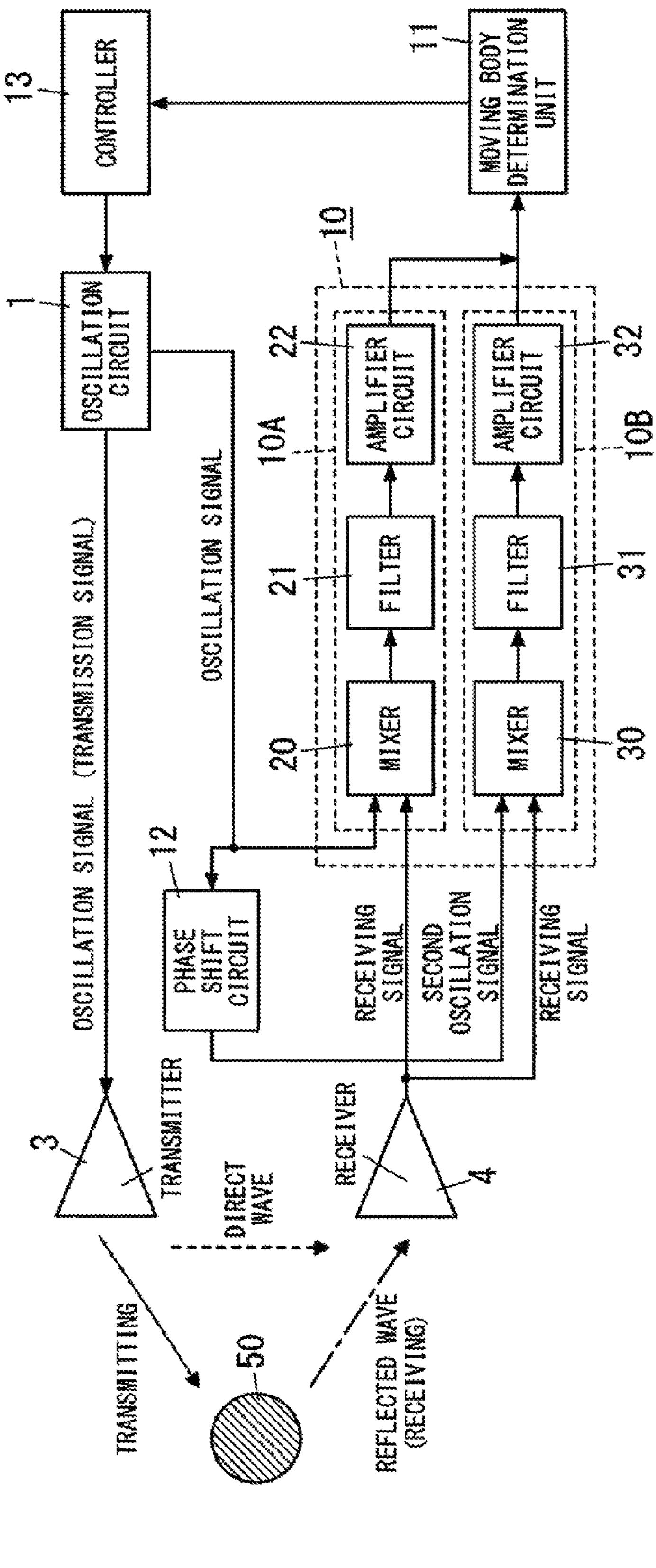
(74) *Attorney, Agent, or Firm* — McDermott Will & Emery LLP

(57) **ABSTRACT**

In a malfunction detection mode, a controller is configured to compare an output of a phase-detector obtained when controlling to input an oscillation signal to only the phase-detector, with an output of the phase-detector obtained when controlling to input the oscillation signal to both of a transmitter and the phase-detector. If a change (difference) of signal levels of the outputs is equal to or more than a prescribed threshold, the controller determines that there is no malfunction in the transmitter and a receiver. If the change of the signal levels is less than the prescribed threshold, the controller determines that there is a malfunction in the transmitter or the receiver.

18 Claims, 3 Drawing Sheets





CONTROLLER
13
MOVING BODY DETERMINATION UNIT
11
OSCILLATION CIRCUIT
1
10
OSCILLATION SIGNAL (TRANSMISSION SIGNAL)
OSCILLATION SIGNAL
10A
10B
22
AMPLIFIER CIRCUIT
32
AMPLIFIER CIRCUIT
21
FILTER
31
FILTER
20
MIXER
30
MIXER
12
PHASE SHIFT CIRCUIT
RECEIVING SIGNAL
SECOND OSCILLATION SIGNAL
RECEIVING SIGNAL
3
TRANSMITTER
DIRECT WAVE
RECEIVER
4
TRANSMITTING
50
REFLECTED WAVE (RECEIVING)

FIG. 1 A

FIG. 1 B

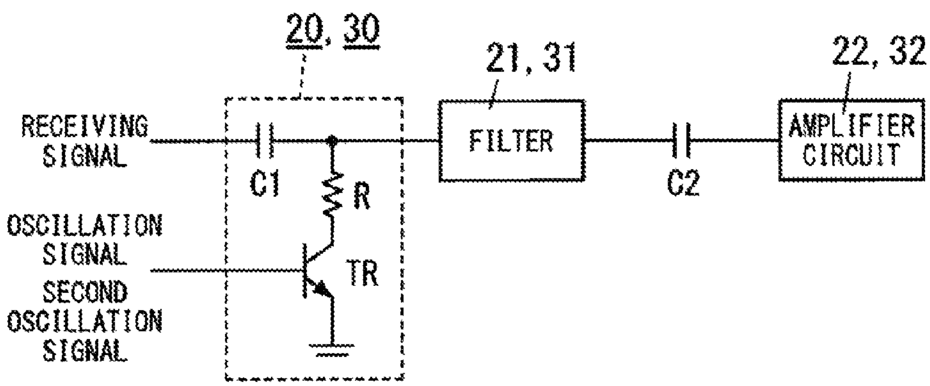
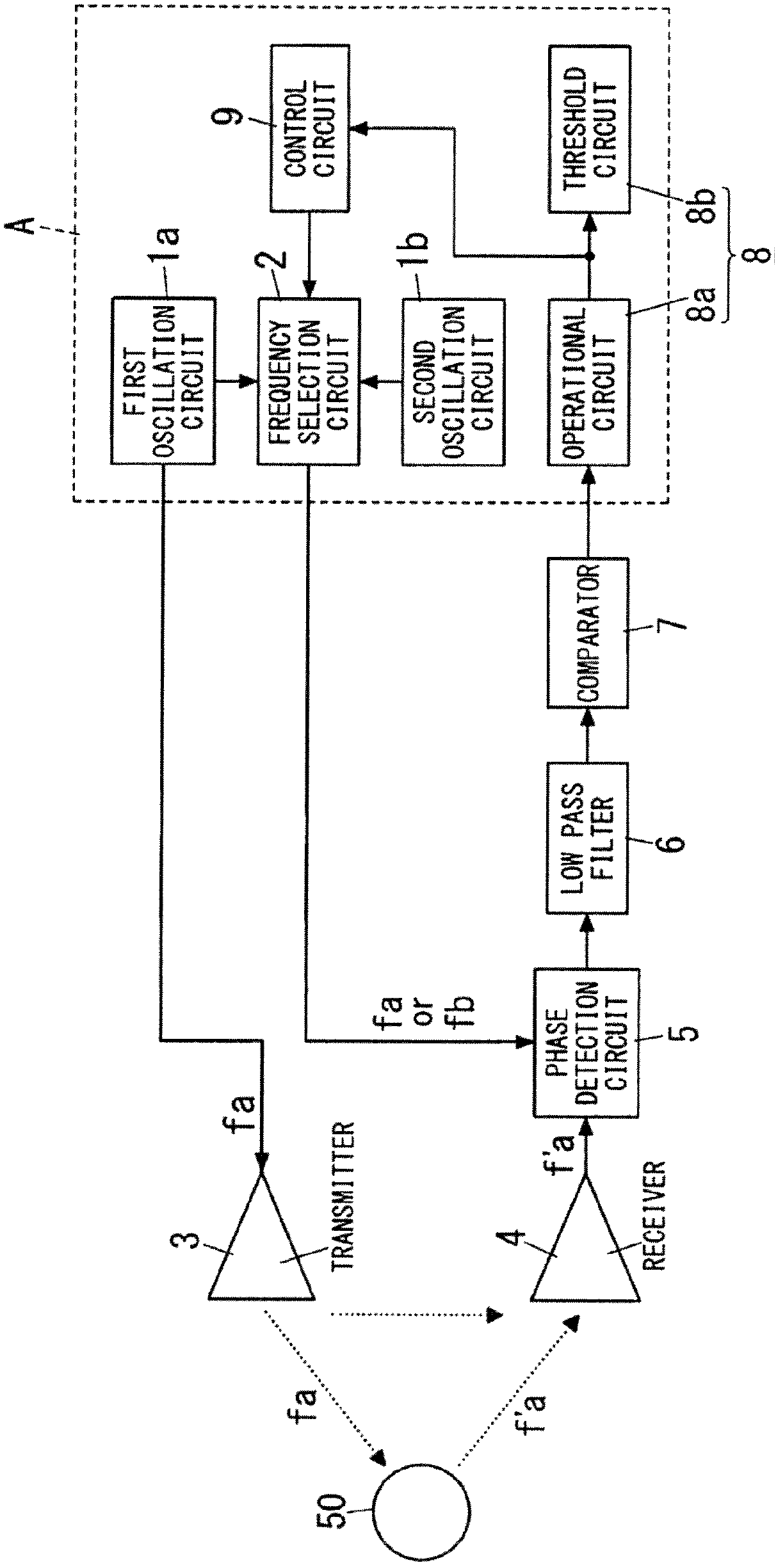

20, 30
21, 31
22, 32
RECEIVING SIGNAL
C1
R
FILTER
C2
AMPLIFIER CIRCUIT
OSCILLATION SIGNAL
SECOND OSCILLATION SIGNAL
TR

FIG. 2 PRIOR ART



MOVING BODY DETECTOR

RELATED APPLICATIONS

This application is the U.S. National Phase under 35 U.S.C. §371 of International Application No. PCT/JP2012/074321, filed on Sep. 24, 2012, which in turn claims the benefit of Japanese Application No. 2011-219786, filed on Oct. 4, 2011, the disclosures of which Applications are incorporated by reference herein.

TECHNICAL FIELD

The invention relates generally to moving body detectors and, more particularly, to a moving body detector that transmits, to a space to be monitored, continuous energy waves, such as ultrasonic waves or radio waves, and detects a frequency shift of a reflected wave generated due to movement of an object within the space to be monitored, thereby detecting presence of the object moving within the space to be monitored.

BACKGROUND ART

Conventionally, there has been a moving body detector described in Japanese Published Unexamined Patent Application No. 2009-281890. The conventional moving body detector in the above-mentioned document, as shown in FIG. **2**, includes a first oscillation circuit **1***a*, a second oscillation circuit **1***b*, a frequency selection circuit **2**, a transmitter **3**, a receiver **4**, a phase detection circuit **5**, a low pass filter **6**, a comparator **7**, an operational circuit **8***a*, a threshold circuit **8***b*, and a control circuit **9**. The first oscillation circuit **1***a* is configured to oscillate a transmission signal having a frequency fa, and the second oscillation circuit **1***b* is configured to oscillate a reference signal having a frequency fb that is different from the frequency of the transmission signal. The transmitter **3** is configured to transmit ultrasonic waves to a space to be monitored, when receiving the transmission signal outputted from the first oscillation circuit **1***a*. The receiver **4** is configured to output a receiving signal, when receiving a reflected wave generated due to reflection of the ultrasonic waves by an object (a moving body) **50** that exists within the space to be monitored. The phase detection circuit **5** is configured to mix the receiving signal and any one of the transmission signal and the reference signal, to obtain a Doppler signal according to a frequency difference between the receiving signal and the any one. The frequency selection circuit **2** is configured to switch the transmission signal and the reference signal inputted to the phase detection circuit **5**. The low pass filter **6** is configured to remove unnecessary high frequency components from the Doppler signal outputted from the phase detection circuit **5**. The comparator **7** is configured to compare the Doppler signal outputted from the low pass filter **6**, with a predetermined reference value, to convert into a binary signal. The operational circuit **8***a* is configured to perform an operational processing of the binary signal outputted from the comparator **7**. The threshold circuit **8***b* is configured to detect the moving body **50** within the space to be monitored, based on an operation result by the operational circuit **8***a*, to output a detection signal. The control circuit **9** is configured to have a moving body detection mode of detecting the moving body **50** and a malfunction detection mode of detecting whether or not the detector is normally operating. In the moving body detection mode, the control circuit **9** is configured to control the frequency selection circuit **2** to input the transmission signal to the phase detection circuit **5**. In the malfunction detection mode, the control circuit **9** is configured to control the frequency selection circuit **2** to input the reference signal to the phase detection circuit **5**.

In the case where the control circuit **9** operates in the moving body detection mode, the transmitter **3** transmits, to the space to be monitored, the ultrasonic waves having the same frequency as the transmission signal, when receiving the transmission signal having the frequency fa from the first oscillation circuit **1***a*. Then, the receiver **4** receives the reflected wave having a frequency f'a generated due to reflection of the ultrasonic waves by the moving body **50** that exists within the space to be monitored and then outputs, to the phase detection circuit **5**, the receiving signal having the same frequency as the reflected wave. The phase detection circuit **5** mixes the receiving signal, and the transmission signal that is outputted from the first oscillation circuit **1***a* via the frequency selection circuit **2**, and then outputs the Doppler signal according to the frequency difference between those signals. Then, the low pass filter **6** removes unnecessary high frequency components from the Doppler signal outputted from the phase detection circuit **5**, and then the comparator **7** converts the Doppler signal into the binary signal to output to the operational circuit **8***a*. The operational circuit **8***a* performs the operational processing of the binary signal to obtain a moving speed of the moving body **50**. Then, when the obtained moving speed exceeds a prescribed value, the threshold circuit **8***b* determines that the moving body **50** exists within the space to be monitored, and then outputs the detection signal.

Here, when, in the moving body detection mode, the moving body **50** does not exist within the space to be monitored or remains stationary within the space to be monitored, the frequencies of the receiving signal and the transmission signal mixed by the phase detection circuit **5** are equal to each other, and accordingly, it is impossible to obtain the Doppler signal. So, in the conventional moving body detector, to detect whether or not the detector is normally operating, the control circuit **9** operates in the malfunction detection mode and controls the frequency selection circuit **2** to input, to the phase detection circuit **5**, the reference signal having the frequency fb that is different from that of the transmission signal. Accordingly, the phase detection circuit **5** mixes the signals having the frequencies different from each other, thereby obtaining a pseudo Doppler signal. Therefore, it is possible to detect whether or not the detector is normally operating, through comparing a result of an operational processing of the pseudo Doppler signal performed by the operational circuit **8***a*, with a predetermined threshold. That is, it is possible to determine that the detector is normally operating when the result of the operational processing of the pseudo Doppler signal agrees with the predetermined threshold, and that there is a malfunction such as disconnection in any of circuits constituting the detector when the result thereof disagree with the predetermined threshold.

In this conventional moving body detector, the first oscillation circuit **1***a*, second oscillation circuit **1***b*, frequency selection circuit **2**, operational circuit **8***a*, threshold circuit **8***b* and control circuit **9** are configured by a microcomputer. The microcomputer executes a program, thereby achieving the functions of the above-mentioned circuits. Therefore, it is possible to realize the first oscillation circuit **1***a*, second oscillation circuit **1***b* and frequency selection circuit **2** through utilizing a timer function provided in the microcomputer, and realize the above-mentioned malfunction detection function with only changing software without seriously changing hardware.

However, it is required that the conventional moving body detector includes two oscillation circuits **1***a*, **1***b*, of which the oscillation frequencies are different from each other, in order to realize the malfunction detection function. In addition, if the oscillation circuits **1***a*, **1***b* and the like are configured by the microcomputer, two of plural timers in the microcomputer may be occupied to output two signals (the transmission signal and reference signal) of which the frequencies are different from each other.

As explained above, because the conventional moving body detector requires a plurality of pieces of hardware (the oscillation circuits **1***a* and **1***b*, or two or more timers of microcomputer) having the same functions, there is a possibility that the cost or the size of the detector is increased with addition of the malfunction detection function.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a moving body detector, which can achieve addition of a malfunction detection function, while suppressing increase in the cost or the size.

A moving body detector of the present invention includes: an oscillator configured to output an oscillation signal having a prescribed frequency; a transmitter configured to transmit, to a space to be monitored, continuous energy waves of which amplitude is periodically changed according to the oscillation signal outputted from the oscillator; a receiver configured to output a receiving signal, when receiving a reflected wave generated due to reflection of the continuous energy waves by an object that exists within the space to be monitored; a phase-detector configured to mix the oscillation signal and the receiving signal to obtain a Doppler signal according to a frequency difference between the oscillation signal and the receiving signal; a detector configured to detect a moving body within the space to be monitored, by processing the Doppler signal, to output a detection signal; and a controller configured to control the oscillator, transmitter, receiver, phase-detector and detector, and alternatively switch a moving body detection mode of detecting the moving body and a malfunction detection mode of detecting presence or absence of malfunction occurrence. In the moving body detection mode, the controller is configured to control to input the oscillation signal to the transmitter and the phase-detector, and make the phase-detector output the Doppler signal according to the frequency difference between the oscillation signal and the receiving signal. In the malfunction detection mode, the controller is configured to compare an output of the phase-detector obtained when controlling to input the oscillation signal to only the phase-detector, with an output of the phase-detector obtained when controlling to input the oscillation signal to both of the transmitter and the phase-detector, to detect the presence or absence of the malfunction occurrence.

According to this configuration, it is possible to achieve addition of a malfunction detection function, while suppressing increase in the cost or the size.

In the moving body detector, preferably, in the malfunction detection mode, the controller is configured to compare the output of the phase-detector obtained when controlling to input the oscillation signal to only the phase-detector, with an output of the phase-detector obtained after shifting from a state of inputting the oscillation signal to only the phase-detector to a state of inputting the oscillation signal also to the transmitter in addition to the phase-detector, to detect the presence or absence of the malfunction occurrence.

In the moving body detector, preferably, in the malfunction detection mode, the controller is configured to compare the output of the phase-detector obtained when controlling to input the oscillation signal to both of the transmitter and the phase-detector, with an output of the phase-detector obtained after shifting from a state of inputting the oscillation signal to both of the transmitter and the phase-detector to a state of inputting the oscillation signal to only the phase-detector through stopping inputting the oscillation signal to the transmitter, to detect the presence or absence of the malfunction occurrence.

In the moving body detector, preferably, the phase-detector includes: a first phase detection block configured to mix the oscillation signal and the receiving signal to obtain the Doppler signal according to the frequency difference between the oscillation signal and the receiving signal; and a second phase detection block configured to mix the receiving signal and a second oscillation signal obtained by shifting a phase of the oscillation signal through a phase shifter, to obtain a Doppler signal according to a frequency difference between the receiving signal and the second oscillation signal.

In the moving body detector, preferably, the phase shifter is configured to shift the phase so that a phase difference between the oscillation signal and the second oscillation signal agrees with substantially $\pi/2$.

In the moving body detector, preferably, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

In the moving body detector, preferably, in the malfunction detection mode, the controller is configured to compare the output of the phase-detector obtained when controlling to input the oscillation signal to only the phase-detector, with an output of the phase-detector obtained when controlling to input neither the oscillation signal nor the receiving signal to the phase-detector, to detect the presence or absence of the malfunction occurrence in the phase-detector.

In the moving body detector, preferably, the oscillator is configured by a microcomputer that is provided with a timer, and is configured to oscillate the oscillation signal with the timer.

In the moving body detector, preferably, the controller is configured to perform a processing of detecting malfunction in the malfunction detection mode before switching to the moving body detection mode.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described in further details. Other features and advantages of the present invention will become better understood with regard to the following detailed description and accompanying drawings where:

FIG. **1**A is a block diagram illustrating a moving body detector according to an embodiment of the present invention;

FIG. **1**B is a circuit diagram illustrating a mixer of the moving body detector according to the embodiment of the present invention; and

FIG. **2** is a block diagram illustrating a conventional moving body detector.

BEST MODE FOR CARRYING OUT THE INVENTION

An embodiment of a moving body detector according to the present invention will be described below in detail, referring to the drawings. In the present embodiment, ultrasonic waves are transmitted as continuous energy waves, similarly to a conventional moving body detector. However, technical ideas of the present invention can be applied also in a case where radio waves are transmitted instead of the ultrasonic waves. Configuration elements having functions similar to the conventional moving body detector are assigned with same reference numerals, and explanations thereof will be omitted appropriately.

As shown in FIG. **1**A, the moving body detector of the present embodiment includes an oscillation circuit **1** (an oscillator), a transmitter **3**, a receiver **4**, a phase-detector **10**, a moving body determination unit **11** (a detector), a phase shift circuit **12** (a phase shifter), and a controller **13**. The oscillation circuit **1** is configured to be capable of outputting an oscillation signal having a frequency of several tens of kilohertz via each of two output terminals separately. The transmitter **3** is configured to transmit, to a space to be monitored, ultrasonic waves having the same frequency (several tens of kilohertz) as the oscillation signal, when receiving the oscillation signal outputted from one of the two output terminals of the oscillation circuit **1**. When receiving the ultrasonic waves coming from the space to be monitored, the receiver **4** is configured to convert the ultrasonic waves into an electrical signal (a receiving signal) to output the converted receiving signal to the phase-detector **10**. The phase shift circuit **12** is configured to shift a phase of the oscillation signal, outputted from the other of the two output terminals of the oscillation circuit **1**, by $\pi/2$. Hereinafter, the oscillation signal in which the phase is shifted by the phase shift circuit **12** is referred as to a second oscillation signal.

The phase-detector **10** includes a first phase detection block **10**A and a second phase detection block **10**B. The first phase detection block **10**A includes a mixer **20**, a filter **21** and an amplifier circuit **22**. The second phase detection block **10**B includes a mixer **30**, a filter **31** and an amplifier circuit **32**. The mixer **20** is configured to mix (multiply) the oscillation signal and the receiving signal to output components (signals) of a frequency difference between the two signals, and a sum of frequencies of the two signals. Similarly, the mixer **30** is configured to mix (multiply) the second oscillation signal and the receiving signal to output components (signals) of a frequency difference between the two signals, and a sum of frequencies of the two signals. Each of the mixers **20**, **30** includes: a capacitor C**1** that cuts a direct current component from the receiving signal; and an NPN bipolar transistor TR in which a collector is connected to an output side of the capacitor C**1** via a resistor R and an emitter is grounded, as shown in FIG. **1**B for example. When the oscillation signal (or the second oscillation signal) is inputted to a base of the bipolar transistor TR, the mixed two kinds of signals (the component of the frequency difference and the component of the sum of the frequencies) are outputted from a connection point between the resistor R and capacitor C**1**.

The filter **21** includes a low pass filter, and is configured to allow, from among the two kinds of signals outputted from the mixer **20**, only the signal (Doppler signal) of the component of the frequency difference between the oscillation signal and the receiving signal to pass through. Similarly, the filter **31** includes a low pass filter, and is configured to allow, from among the two kinds of signals outputted from the mixer **30**, only the signal (Doppler signal) of the component of the frequency difference between the second oscillation signal and the receiving signal to pass through. The amplifier circuits **22**, **32** are configured to amplify the Doppler signals passing through the filters **21**, **31**, respectively. Although not illustrated in FIG. **1**A, a capacitor C**2** for cutting a direct current is inserted between the filter **21** and amplifier circuit **22**, and similarly a capacitor C**2** is inserted between the filter **31** and amplifier circuit **32**.

The moving body determination unit **11** is configured to determine (detect) that a moving body **50** exists within the space to be monitored and output a detection signal, when determining that signal levels of the Doppler signals amplified by the amplifier circuits **22**, **32** correspond to movement components. The detection signal from the moving body determination unit **11** is transmitted to, for example, an ECU (Electronic Control Unit) of a vehicle, and the ECU notifies the surroundings of intrusion of a suspicious person into the vehicle, through issuing alarm sounds (horn sounds) for example.

The controller **13** is configured to control the oscillator circuit, transmitter, receiver, phase-detector, phase shift circuit and moving body determination unit, and alternatively switch a moving body detection mode of detecting the moving body and a malfunction detection mode of detecting presence or absence of malfunction occurrence. In the moving body detection mode, the controller **13** is configured to make the oscillator circuit **1** input the oscillation signal to the transmitter **3** and phase-detector **10**, to make the moving body determination unit **11** detect the moving body based on the Doppler signal outputted from the phase-detector **10**.

Here, the receiver **4** may receive an ultrasonic wave (reflected wave) reflected by a stationary object, such as a windowpane or a door, in a closed space as in the vehicle. Further, the receiver **4** may receive directly a part of the ultrasonic waves outputted from the transmitter **3**. If no moving body exists within the space to be monitored, a frequency of the receiving signal agrees with that of the oscillation signal (transmission signal), and the component of the frequency difference between the oscillation signal (or the second oscillation signal) and the receiving signal becomes zero. Therefore, the filer **21** (or filter **31**) outputs only a signal of a direct current component according to a phase difference between the oscillation signal (or the second oscillation signal) and the receiving signal. That is, in a case where at least one of the transmitter **3** and receiver **4** fails and does not operate, the signal outputted from the mixer **20** (or mixer **30**) becomes a direct current signal having a level according to only a phase of the oscillation signal (or the second oscillation signal). This direct current signal is not required in the moving body detection mode, and accordingly is cut with the capacitor C**2**. On the other hand, when the level of the signal outputted from each of the filers **21**, **31** is changed with a change of the phase difference between the signals inputted to each of the mixers **20**, **30**, a signal according to the level change is outputted from each of the amplifier circuit **22**, **32**.

Therefore, it is possible to detect presence or absence of malfunction occurrence, through comparing an output of the phase-detector **10** obtained when controlling to input the oscillation signal to only the phase-detector **10**, with an output of the phase-detector **10** obtained when controlling to input the oscillation signal to both of the transmitter **3** and the phase-detector **10**.

So, in the malfunction detection mode, the controller **13** first acquires the output of the phase-detector **10** obtained when controlling to input the oscillation signal to only the phase-detector **10**, from the moving body determination unit **11**. Further, after the output change of the phase-detector **10** is reduced, the controller **13** acquires the output of the phase-detector **10** obtained when controlling to input the oscillation signal to both of the transmitter **3** and the phase-detector **10**, from the moving body determination unit **11**, and compares a signal level of the former output with that of the latter output.

That is, the controller **13** is configured to compare the output of the phase-detector **10** obtained when controlling to input the oscillation signal to only the phase-detector **10**, with an output of the phase-detector **10** obtained after shifting from a state of inputting the oscillation signal to only the phase-detector **10** to a state of inputting the oscillation signal also to the transmitter **3** in addition to the phase-detector **10**.

Then, if a change (difference) of the signal level is equal to or more than a prescribed threshold, the controller determines that there is no malfunction in the transmitter **3** and the receiver **4**. If the change of the signal level is less than the prescribed threshold, the controller determines that there is a malfunction in the transmitter **3** or the receiver **4**. Alternatively, the controller **13** may be configured to compare the output of the phase-detector **10** obtained when controlling to input the oscillation signal to both of the transmitter **3** and the phase-detector **10**, with an output of the phase-detector **10** obtained when controlling to input the oscillation signal to only the phase-detector **10** through stopping inputting the oscillation signal to the transmitter **3**. The controller **13** is configured to output a malfunction detection signal to an external device (e.g., an ECU or the like of a vehicle) when determining that there is a malfunction.

As described above, unlike the conventional moving body detector, the moving body detector of the present embodiment can detect the presence or absence of the malfunction occurrence with only one kind of the oscillation signal, and accordingly can achieve addition of a malfunction detection function, while suppressing increase in the cost or the size. Furthermore, in the present embodiment, the phase difference of $\pi/2$ is set between the oscillation signal and the second oscillation signal, and accordingly, even when a phase difference between the oscillation and receiving signals inputted to one of the first and second phase detection blocks becomes zero, a phase difference between the oscillation and receiving signals inputted to the other does not become zero. Therefore, the moving body detector can securely detect the malfunction occurrence. As the phase difference between the oscillation signal and the second oscillation signal, setting $\pi/2$ is not required, but it is possible to securely detect the malfunction occurrence by setting $\pi/2$, even when the number of the phase detection blocks is minimum (that is, two).

Here, in the malfunction detection mode, the controller **13** may be configured to compare the output of the phase-detector **10** obtained when controlling to previously drive the transmitter **3** and the receiver **4** and input the oscillation signal to both of the transmitter **3** and the phase-detector **10**, with an output of the phase-detector **10** obtained after shifting from a state of inputting the oscillation signal to both of the transmitter **3** and the phase-detector **10** to a state of inputting the oscillation signal to only the phase-detector **10** through stopping inputting the oscillation signal to the transmitter **3**, to detect the presence or absence of the malfunction occurrence.

Also, the moving body detector can detect the presence or absence of the malfunction occurrence with only an output of any one of the first phase detection block **10**A and the second phase detection block **10**B. Here, the moving body detector can detect the presence or absence of the malfunction occurrence more securely, in a case where in the malfunction detection mode the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum. Specifically, the controller may be configured to calculate a sum of a square of an output of the first phase detection block **10**A and a square of an output of the second phase detection block **10**B, obtained when controlling to input the oscillation signal to only the phase-detector **10**, and further calculate a sum of a square of an output of the first phase detection block **10**A and a square of an output of the second phase detection block **10**B, obtained when controlling to input the oscillation signal to both of the transmitter **3** and the phase-detector **10**, and compare the two sums with each other to detect the presence or absence of the malfunction occurrence.

Here, in the malfunction detection mode, the controller **13** may be configured to compare the output of the phase-detector **10** obtained when controlling to input the oscillation signal to only the phase-detector **10**, with an output of the phase-detector **10** obtained when controlling to input neither the oscillation signal nor the receiving signal to the phase-detector **10**. That is, in a state where no receiving signal is inputted, when the oscillation signal (or the second oscillation signal) is inputted to the base of the bipolar transistor TR in the mixer **20** (or mixer **30**), a level of a direct current voltage outputted from the mixer **20** (or mixer **30**) is changed according to the oscillation signal. Therefore, the controller **13** compares the output of the phase-detector **10** obtained when only the oscillation signal is inputted to the phase-detector **10**, with the output thereof obtained when no oscillation signal is inputted thereto, while no receiving signal is inputted, and accordingly, the moving body detector can detect the presence or absence of the malfunction occurrence (failure) in the phase-detector **10**.

Preferably, the controller **13** is configured to perform a processing of detecting malfunction in the malfunction detection mode before switching to the moving body detection mode. That is, because the moving body detector of the present embodiment is intended to detect the moving body in a vehicle during parking, after a driver parks and leaves the vehicle, the controller performs the processing of detecting malfunction in the malfunction detection mode before performing a processing of detecting the moving body in the moving body detection mode. Therefore, the moving body detector can reduce detection mistake of the moving body.

In the present embodiment, the oscillation circuit **1**, phase-detector **10**, moving body determination unit **11**, phase shift circuit **12** and controller **13** may be configured by a microcomputer, similarly to the case of the conventional moving body detector. The microcomputer executes a prescribed program, thereby achieving each function. That is, it is possible to oscillate the oscillation signal with a timer that is provided in the microcomputer. Further, plural timers are not occupied when oscillating the oscillation signal, unlike the conventional moving body detector. In the conventional moving body detector, there is a case where it is required to change an existing microcomputer to another microcomputer in which the number of the timers is larger, to detect the presence or absence of the malfunction occurrence. On the other hand, in the present embodiment, there is a high possibility that the moving body detector can detect the presence or absence of the malfunction occurrence without changing an existing microcomputer.

Although the present invention has been described with reference to certain preferred embodiments, numerous modifications and variations can be made by those skilled in the art without departing from the true spirit and scope of this invention, namely claims.

The invention claimed is:

1. A moving body detector, comprising:

an oscillator configured to output an oscillation signal having a prescribed frequency;

a transmitter configured to transmit, to a space to be monitored, continuous energy waves of which amplitude is periodically changed according to the oscillation signal outputted from the oscillator;

a receiver configured to output a receiving signal, when receiving a reflected wave generated due to reflection of the continuous energy waves by an object that exists within the space to be monitored;

a phase-detector configured to mix the oscillation signal and the receiving signal to obtain a Doppler signal according to a frequency difference between the oscillation signal and the receiving signal;

a detector configured to detect a moving body within the space to be monitored, by processing the Doppler signal, to output a detection signal; and

a controller configured to control the oscillator, transmitter, receiver, phase-detector and detector, and alternatively switch a moving body detection mode of detecting the moving body and a malfunction detection mode of detecting presence or absence of malfunction occurrence,

wherein, in the moving body detection mode, the controller is configured to control to input the oscillation signal to the transmitter and the phase-detector, and make the phase-detector output the Doppler signal according to the frequency difference between the oscillation signal and the receiving signal, and

wherein, in the malfunction detection mode, the controller is configured to compare an output of the phase-detector obtained when controlling to input the oscillation signal to only the phase-detector, with an output of the phase-detector obtained when controlling to input the oscillation signal to both of the transmitter and the phase-detector, to detect the presence or absence of the malfunction occurrence.

2. The moving body detector according to claim **1**, wherein, in the malfunction detection mode, the controller is configured to compare the output of the phase-detector obtained when controlling to input the oscillation signal to only the phase-detector, with an output of the phase-detector obtained after shifting from a state of inputting the oscillation signal to only the phase-detector to a state of inputting the oscillation signal also to the transmitter in addition to the phase-detector, to detect the presence or absence of the malfunction occurrence.

3. The moving body detector according to claim **2**, wherein the phase-detector comprises:

a first phase detection block configured to mix the oscillation signal and the receiving signal to obtain the Doppler signal according to the frequency difference between the oscillation signal and the receiving signal; and

a second phase detection block configured to mix the receiving signal and a second oscillation signal obtained by shifting a phase of the oscillation signal through a phase shifter, to obtain a Doppler signal according to a frequency difference between the receiving signal and the second oscillation signal.

4. The moving body detector according to claim **3**, wherein the phase shifter is configured to shift the phase so that a phase difference between the oscillation signal and the second oscillation signal agrees with substantially $\pi/2$.

5. The moving body detector according to claim **4**, wherein, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

6. The moving body detector according to claim **3**, wherein, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

7. The moving body detector according to claim **1**, wherein, in the malfunction detection mode, the controller is configured to compare the output of the phase-detector obtained when controlling to input the oscillation signal to both of the transmitter and the phase-detector, with an output of the phase-detector obtained after shifting from a state of inputting the oscillation signal to both of the transmitter and the phase-detector to a state of inputting the oscillation signal to only the phase-detector through stopping inputting the oscillation signal to the transmitter, to detect the presence or absence of the malfunction occurrence.

8. The moving body detector according to claim **7**, wherein the phase-detector comprises:

a first phase detection block configured to mix the oscillation signal and the receiving signal to obtain the Doppler signal according to the frequency difference between the oscillation signal and the receiving signal; and

a second phase detection block configured to mix the receiving signal and a second oscillation signal obtained by shifting a phase of the oscillation signal through a phase shifter, to obtain a Doppler signal according to a frequency difference between the receiving signal and the second oscillation signal.

9. The moving body detector according to claim **4**, wherein the phase shifter is configured to shift the phase so that a phase difference between the oscillation signal and the second oscillation signal agrees with substantially $\pi/2$.

10. The moving body detector according to claim **9**, wherein, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

11. The moving body detector according to claim **4**, wherein, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

12. The moving body detector according to claim **1**, wherein the phase-detector comprises:

a first phase detection block configured to mix the oscillation signal and the receiving signal to obtain the Doppler signal according to the frequency difference between the oscillation signal and the receiving signal; and

a second phase detection block configured to mix the receiving signal and a second oscillation signal obtained by shifting a phase of the oscillation signal through a phase shifter, to obtain a Doppler signal according to a frequency difference between the receiving signal and the second oscillation signal.

13. The moving body detector according to claim **12**, wherein the phase shifter is configured to shift the phase so that a phase difference between the oscillation signal and the second oscillation signal agrees with substantially $\pi/2$.

14. The moving body detector according to claim **13**, wherein, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

15. The moving body detector according to claim **12**, wherein, in the malfunction detection mode, the controller is configured to calculate a sum of a square of an output of the first phase detection block and a square of an output of the second phase detection block, and compare results relating to the sum to detect the presence or absence of the malfunction occurrence.

16. The moving body detector according to claim **1**, wherein, in the malfunction detection mode, the controller is configured to compare the output of the phase-detector obtained when controlling to input the oscillation signal to only the phase-detector, with an output of the phase-detector obtained when controlling to input neither the oscillation signal nor the receiving signal to the phase-detector, to detect the presence or absence of the malfunction occurrence in the phase-detector.

17. The moving body detector according to claim **1**, wherein the oscillator is configured by a microcomputer that is provided with a timer, and is configured to oscillate the oscillation signal with the timer.

18. The moving body detector according to claim **1**, wherein the controller is configured to perform a processing of detecting malfunction in the malfunction detection mode before switching to the moving body detection mode.

* * * * *